Quarterly Progress Report

Project No. DE-FC26-05NT42304

Lovelace Biomedical and Environmental Research Institute
Albuquerque, NM

Health Effects of Subchronic Inhalation of Simulated Downwind Coal Combustion Emissions

Calendar Quarter 1

February 3, 2005 – April 30, 2005

Project Director:

Joe L. Mauderly, DVM
Director, National Environmental Respiratory Center
President, Lovelace Biomedical and Environmental Research Institute
Lovelace Respiratory Research Institute
2425 Ridgecrest Dr. SE
Albuquerque, NM 87111
505-348-9432
jmauderl@lrri.org

Contents | Page

1. Executive Summary

This Report describes progress during the first calendar quarter of project DE-FC26-05NT42304 “Health Effects of Subchronic Inhalation of Simulated Downwind Coal Combustion Emissions”. The project was initiated on February 3, 2005.

This project will conduct a comprehensive laboratory-based evaluation of selected respiratory and cardiac health hazards of repeated, subchronic (up to 6 months) inhalation of simulated key components of “downwind” emissions of coal combustion. This project is being performed as an integral part of a joint government-industry program termed the “National Environmental Respiratory Center” (NERC), which is aimed at disentangling the roles of different physical-chemical air pollutants and their sources in the health effects associated statistically with air pollution.

Target ratios of key physical-chemical components of the exposure were set by consensus of an expert workshop. The characterization of the exposure atmosphere and the health assays will be identical to those employed in the NERC protocols used to evaluate other pollution source emissions. The project has two phases, each encompassing multiple tasks. The capability to generate the exposure atmosphere, and pilot studies of the comparative exposure composition using two coal types, will be accomplished in Phase 1. The toxicological study will be conducted using one of the coal types in Phase 2. This project provides 50 % support for the work in Phase 1 and 20% support for the work in Phase 2. The project is now in Phase 1, Task 1. Considerable preliminary work occurred within the NERC program before DOE funding began.

The project is on schedule. Many technical issues are being addressed, but no obstructing issues or problems have arisen. We are projecting that the project will continue as scheduled. Work to date has focused on developing the coal combustion system and identifying specific coal sources (Phase 1).

Two identical combustion systems, consisting of high-temperature electric “drop-tube” furnaces and associated aerosolizers, tubing, and mixing chamber, are being assembled. Two are required because the animal exposures are to be conducted 7 days/week for approximately 8 months, and exposure gaps due to down-time are not acceptable. A furnace design was finalized based on experience in other laboratories and technical advice from the supplier. Two furnaces were procured, and have been installed. A system for generating an aerosol of pulverized coal was designed, constructed, and tested. Work on assembling the rest of the system is underway.

During this reporting period, sources of two appropriate coal types were identified. The project involves generating emissions from a low-sulfur western coal, specifically Powder River Basin (PRB) coal, and a Central Appalachian low-sulfur coal (CALS). We have identified the Black Thunder mine in Campbell County Wyoming as an appropriate source for the PRB coal. We have identified the Jones Fork blending plant in Knott County, Kentucky as an appropriate source for the CALS coal. We have developed an agreement with the Energy and Environment Research Center at the University of North Dakota (EERC) to process and analyze the coals.

Work during the next reporting period will be directed toward completing the assembly of the generation system and obtaining drums the two processed coals.

2. Results of Work During Reporting Period

a. Approach

The general approach taken in this project has not changed from that described in the application. The approach to Phase1, Task 1, involves: 1) collecting information on the use of drop-tube furnaces for laboratory-scale coal combustion; 2) collecting information on potential coal types and resources for obtaining coal and processing it for use in the laboratory; 3) finalizing a design for the drop-tube furnaces to be used in this project; obtaining processed coal; 4) obtaining, installing and testing the furnaces; 5) developing and testing the coal aerosol generator; 6) assembling the emissions generation/modification system; and 7) confirming system operation by generating coal emissions. The work will then proceed to Phase 1, Task 2: the conduct of iterative generation trials with PRB coal.

Acquiring information from other laboratories and technical experts was largely accomplished before the start of this project, and has been completed since project start. These contacts are summarized in Table 1.

Table 1. Completed Contacts for Technical Information

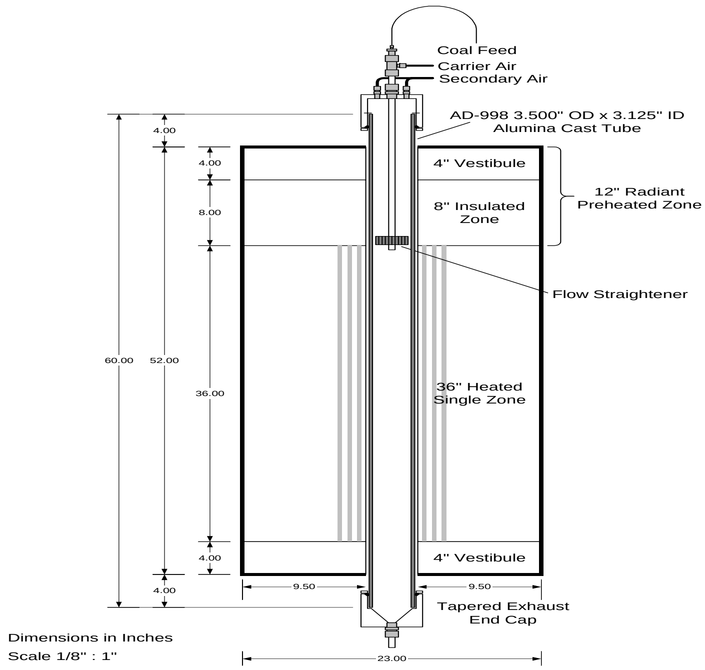
<u>Site Visits</u>:
- Adel Sarofim, University of Utah (brought to our laboratory for consultation)
- JoAnn Lighty, University of Utah
- Steve Benson and Jason Laumb, EERC, University of North Dakota
- Kevin Davis, Reaction Engineering International, Salt Lake City, UT
- Bill Linak and Andy Miller, EPA/ORD, Research Triangle Park
- Lung Chi Chen, New York University

<u>Technical Discussions</u>:
- Jost Wendt, University of Arizona
- Larry Monroe and John Jansen, Southern Company
- Constantinos Sioutas, University of Southern California
- Bill Aljoe, DOE/NETL
- Steve Winter and Pete Rosendale, CONSOL

After learning the best features of other drop-tube furnaces and coal feeding devices, and defining key operating issues and problems to avoid, we developed specifications, contacted suppliers, and determined the best vendor on the basis of technical competence to provide a custom-designed unit, cost, and delivery schedule. We purchased two identical split tube furnaces and associated control systems from Thermcraft, Inc. (Winston-Salem, NC).

The Furnaces have 4-inch internal diameters to accommodate 3-inch ceramic tubes in which the coal will be combusted. The 12780-watt furnaces have silicon carbide heating elements and an operating temperature range of 1400-1510^{o}C. The furnaces are insulated with light weight ceramic fiber, and have steel outer shells that are arranged in two halves that can be opened to service the heating elements and combustion tube. The heating elements are controlled by Yokogawa UP350 digital controllers which sense temperature with ceramic-sheathed thermocouples and provide current to the furnaces from 240 volt, 3 phase, 60 Hz power supply. The design of the furnaces is illustrated in Figure 1.

Figure 1. Cross-Sectional Diagram Showing Furnace Design and Dimensions



Specially-designed coal inlet sections, end caps for holding the ceramic combustion tube, and supports for the furnaces were designed in-house and fabricated locally. These items are diagrammed in Figure 2. Figure 3 presents a photograph of a furnace unit being mounted on its support. The 6-ft stepladder in the background provides size perspective.

Figure 2. Design of Components of the Furnace System

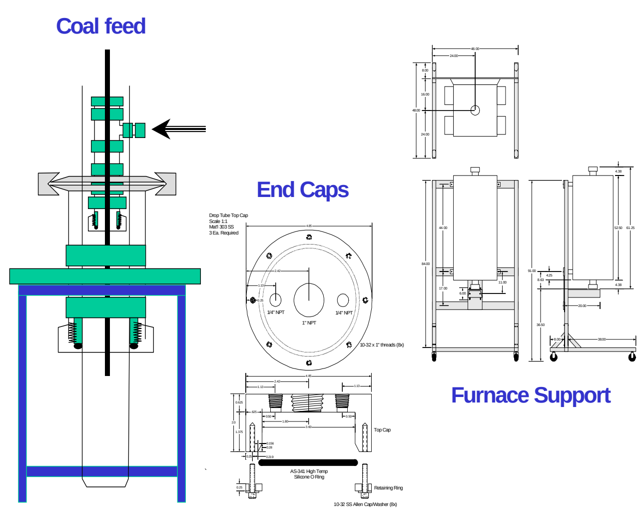
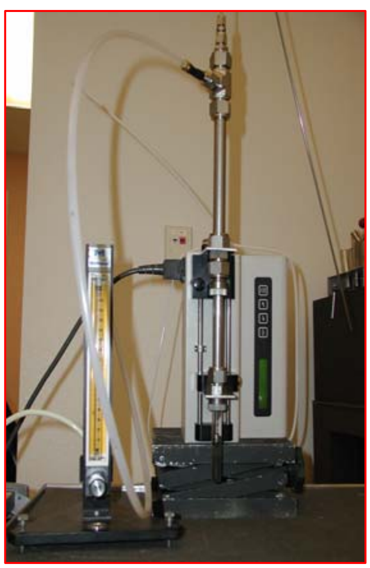


Figure 3. Furnace Unit Being Mounted to Support

A device for aerosolizing pulverized coal and feeding the aerosol into the top of the furnace was designed, based largely on the device used by EPA – the most successful design in other laboratories. In concept, coal dust from the surface of dust contained in a small reservoir tube is entrained as an aerosol into air flowing into the reservoir tube and out through a small-diameter extraction tube placed a very small distance above the surface of the dust.   Only a few grams of coal dust are required per day, so the feed system is a small bench-top unit. The reservoir tube is loaded, the extraction tube is lowered to an appropriate height above the coal surface, airflow is initiated at an appropriate rate, and the extraction tube is maintained at a constant height above the coal dust by a syringe pump. Operating variables determining the feed rate are the airflow rate and the speed at which the syringe pump advances the extraction tube. This system was assembled, tested, and optimized, and is now ready for connection to the furnace. A photo of the coal feed system is presented in Figure 4.

Figure 4. Photograph of Coal Feed System



Both furnaces and controllers have been mounted in the laboratory and connected to power. One furnace has been activated and operated sufficiently to burn out the fumes that naturally are emitted from a new unit. The coal feed unit has been moved to the laboratory housing the furnaces. The next step is to construct the connections between the furnace and the chamber to be used for mixing emissions with additional materials to achieve the desired final exposure atmosphere. The emissions from the ceramic tube will have to be temperature quenched. To do this, we obtained chiller units that can provide cooling via water-based heat exchangers.

In parallel with the assembly of the combustion system, we have worked to identify appropriate sources for the two coal types. Consensus was developed at our workshop to use PRB and CALS coals, as representative of coals comprising the majority of the steam market, and likely to continue to do so. PRB coal is a low-sulfur (typically 0.5% or less) sub-bituminous coal, and CALS coal is at the lower end of the sulfur content range for eastern bituminous coals (typically approximately 1.5%).

The source for PRB coal was selected on the basis of information obtained during our visit to EERC. That laboratory has generated emissions using drop-tube furnaces as well as pilot-scale coal-fired units configured more like full-scale boiler units. They have used a variety of coals, and have capability for processing raw coal to pulverized form. They also have capability for analyzing coal samples. We developed an agreement for EERC to receive, process, and analyze the coals to be used in this project. Their recommendation was to use coal from the Black Thunder open-pit mine in Campbell County, Wyoming. This coal comes from the Wyodek bed, which provides approximately 30% of the total coal consumed in the U.S. (*Annual Coal Report, DOE/EIA 0584, 2003*). Campbell County is the largest producing area, and until recently, the Black Thunder mine was the largest producing mine working that coal bed (it is now second largest). A recent analysis of this source indicated 0.3% sulfur, 33% volatiles, 35% fixed carbon, and 5% ash. EERC has considerable experience with coal from this source, using it in several projects as representative of PRB coals in composition and combustion characteristics. EERC has established procedures for obtaining and processing this coal, and using it will allow results from this project to be related to results from other studies.

The most appropriate source for CALS coal was less obvious. We began by examining the demographics of coal types. There are four principal low-sulfur bituminous coal beds in the Central Appalachian region. By volume produced, the two principal beds in Eastern Kentucky are the Hazard 5-A and Elkhorn 3, and the two principal beds in Southwestern West Virginia are the Stockton-Lewiston and Lower Kittanning. Together, these beds produce approximately 8% of the total coal consumed in the U.S. (*Annual Coal Report, DOE/EIA 0584, 2003*), essentially all for the steam market. The Eastern Kentucky beds produce slightly more than the Southwestern West Virginia beds.

We then consulted with Larry Monroe of Southern Company, one of the largest Southeastern utility consumers of coal, and Bill Aljoe of DOE/NETL, who has numerous contacts among the coal industry. Those discussions led us to Steve Winter at CONSOL, one of the major coal producers of the region, and his colleague Pete Rosendale, who has the appropriate technical information on their coal sources and analyses. The Jones Fork blending plant in Knott County, Kentucky was identified as the most appropriate source. This plant blends, processes, and ships coal from several regional underground mines working the appropriate coal beds and shipped 3 million tons in 2004, all for the steam market. Approximately 75% of the stock comes from one mine working the Elkhorn 3 bed. Combined biannual analytical data for that plant during 2001-2004 indicate 1.5% sulfur, 39% volatiles, 53% fixed carbon, and 9% ash. We view that source as appropriate for this project, and CONSOL has agreed to work with us to obtain our sample.

b. Results and Discussion

Other than the progress described above, there are no specific technical results to report during this quarter. The project will produce preliminary results during the next quarter in the form of coal analyses and initial results of coal combustion.

c. Conclusions

The only "conclusion" resulting thus far is that the project continues to appear technically feasible and should progress as planned and according to schedule.

3. Milestones

The only milestone pertinent to this reporting period is Phase 1, Task 1 "Assemble Drop-Tube Furnace and Emissions Modification System". That milestone is not scheduled to be completed until August 2005. At present, we are on schedule, and are aware of no issues that should prevent completion of this milestone on time.

4. Cost and Schedule Status

a. Cost Status

DOE expenses as of 4/30/05:	$33,031.33
LRRI cost share as of 4/30/05:	$ 6,606.27
Other cost share as of 4/30/05:	$26,425.06
Total expenditures as of 4/30/05:	$66,062.66

b. Schedule Status

The project is on schedule.

5. Significant Accomplishments

Significant accomplishments were described in detail above. In summary, we have:

- Designed and procured major components of emissions generation system
- Identified appropriate coal sources and resources for processing and analysis

6. Problems, Delays, and Corrective Actions

We have not encountered any problems or delays that have obstructed progress significantly. All challenges to date have been related to technical and logistical issues that we anticipated, and have addressed successfully.

7. Technology Transfer Activities

There have been no technology transfer activities or issues to date. It is not anticipated that this project will generate any intellectual property or technical advances that will raise technology transfer issues. The product of this project is explicitly information on the health effects of exposure to modified coal emissions, and that information is to be communicated to the scientific community, public, and other stakeholders through peer-reviewed, open literature publications.